Progress on ESS Project Construction

Roland Garoby – Technical Director

15 May 2017
Progress on ESS Project Construction

ESS facility and construction project

• Status of design and progress in realization
• Global Project status
• Summary
High Power Linear Accelerator:
- Energy: 2 GeV
- Rep. Rate: 14 Hz
- Current: 62.5 mA

16 Instruments in Construction budget
Committed to deliver 22 instruments by 2028
Peak flux ~30-100 brighter than the ILL

Target Station:
- He-gas cooled rotating W-target (5MW average power)
- 42 beam ports

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Committed to deliver 22 instruments by 2028
Peak flux ~30-100 brighter than the ILL

Environmental goal ("Sustainability")
- Energy responsible
- Renewable energy
- Recyclable heat

Total cost: 1843 M€ 2013
Construction plan

- 2009: Decision to Site ESS in Lund
- 2014: Construction Starts on Green Field Site
- 2012: ESS Design Update Phase Complete
- 2019-20: Machine Ready for 1st Beam on Target
- 2023: ESS Starts User Program
- 2025: ESS Construction Phase Complete
Financing

Host Countries Sweden and Denmark
Construction  47.5%  Cash Investment ~ 97%
Operations  15%

Non Host Member Countries
Construction  52.5%  In-kind Deliverables ~ 70%
Operations  85%

(Jan 2013 pricing)  M €

<table>
<thead>
<tr>
<th>Category</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional Facilities</td>
<td>531.9</td>
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<tr>
<td>Extra CF investment by host countries</td>
<td>-93.0</td>
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<tr>
<td>Accelerator Systems</td>
<td>510.2</td>
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<td>Target Systems</td>
<td>155.2</td>
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<td>Integrated Control System</td>
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<td>Design &amp; Engineering</td>
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<td>Neutron Scattering Systems</td>
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<td>Project Support &amp; Administration and Licensing</td>
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<tr>
<td>Contingency</td>
<td>158.2</td>
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<tr>
<td><strong>Total Construction Budget</strong></td>
<td><strong>1843.0</strong></td>
</tr>
</tbody>
</table>
ESS partners

Aarhus University
Atomki - Institute for Nuclear Research
Bergen University
CEA Saclay, Paris
Centre for Energy Research, Budapest
Centre for Nuclear Research, Poland, (NCBJ)
CNR, Rome
CNRS Orsay, Paris
Cockcroft Institute, Daresbury
Elettra – Sincrotrone Trieste
ESS Bilbao
Forschungszentrum Jülich
Helmholtz-Zentrum Geesthacht
Huddersfield University
IFJ PAN, Krakow
INFN, Catania
INFN, Legnaro
INFN, Milan
Institute for Energy Research (IFE)
Rutherford-Appleton Laboratory, Oxford (ISIS)
Kopenhagen University
Laboratoire Léon Brilouin (LLB)
Lund University
Nuclear Physics Institute of the ASCR
Oslo University
Paul Sherrer Institute
Polska Grupa Energetyczna - PGE
Roskilde University
Tallinn Technical University
Technical University of Denmark
Science and Technology Facilities Council
University of Tartu
Uppsala University
WIGNER Research Centre for Physics
Wroclaw University of Technology
Warsaw University of Technology
Zurich University of Applied Sciences (ZHAW)
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Technical University Munich
Technical University of Denmark
University of Hamburg
University of Tartu
Uppsala University
WIGNER Research Centre for Physics
Wroclaw University of Technology
Warsaw University of Technology
Zurich University of Applied Sciences (ZHAW)

45+ Institutions as IKC Partners

250+IKC Work Packages
ESS partners

Institutions as IKC Partners

250+IKC Work Packages

IPAC17
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ESS linac

- Average beam power of 5 MW
- Peak beam power of 125 MW
- Acceleration to 2 GeV
- Peak proton beam current of 62.5 mA
- Pulse length of 2.86 ms at a rate of 14 Hz (4% duty factor)

96% of acceleration will be provided by superconducting cavities supplied by 150 high power RF sources (one per cavity):

- 80% of the RF power sources delivering over 1.1 MW of peak RF power
- The RF system is the cost driver for the ESS accelerator.
Accelerator components benefit from expert competencies all across Europe
Accelerator components benefit from expert competencies all across Europe
Test Stands 1, 2 in Lund and FREIA in Uppsala – Hands-on work has begun!

MOPVA089 The Cryomodule Test Stands for the European Spallation Source (E. A. Conejero – ESS)
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MOPVA089 The Cryomodule Test Stands for the European Spallation Source (E. A. Conejero – ESS)
Ion source in Catania at nominal parameters
Ion source in Catania at nominal parameters.
MEBT design and fabrication are in progress

Buncher Cavity Production and Heat Treatment

Strip Line Chopper Tests Complete

THPIK082 Quadrupole Magnet Design for the ESS MEBT (D. Fernandez-Canoto – ESS Bilbao)
DTL recent achievements

- 5 tanks

Tank 4: forged 304 L stainless steel

DTL design work at ESS and in Legnaro, 3.6 ->90 MeV.

[Picture from CERN Linac4]

Drift tube prototypes
Spoke Cavities design & prototype performances

Spoke cavity prototype test results (Jan15 – Feb16):

- Excellent performances, well within specifications (both on Eacc & Qo)

Cryomodule with 2 cavities

THOB3 ESS SRF Linear Accelerator Components Preliminary Results and Integration (C. Darve (ESS)
MOPVA090 ESS Superconducting RF Collaboration (C. Darve – ESS)
The INFN LASA cavity was successfully tested @ 2 K, exceeding the ESS specifications.

A soft MP barrier was easily conditioned. This barrier matches with simulations.

HOM near 5th machine line

100 W CW cryo power, i.e. 16.7 MV/m @ Q₀ 5 x 10⁹

f = 1741.8 MHz (> 19 MHz from machine line)
Δf < 1 MHz from simulations (f = 1742.4 MHz).
The INFN LASA cavity was successfully tested @ 2 K, exceeding the ESS specifications.

**Soft Multipacting barrier**

Power Rise @ 2 K

- **MOPVA041** Vertical Test Results on ESS Medium and High Beta Elliptical Cavity Prototypes equipped with Helium Tank (E. Cenni – CEA)
- **MOPVA040** Development Status of the Elliptical Cavity Cryomodules for ESS (F. Peauger – CEA)
- **MOPVA060** Fabrication and Treatment of the ESS Medium Beta Prototype Cavities (L. Monaco – INFN)
- **MOPVA061** Quench and Field Emission Diagnostics for the ESS Medium-Beta Prototypes Vertical Tests at LASA (M. Bertucci – INFN)
- **MOPVA063** Vertical Tests of ESS Medium Beta Prototype Cavities at LASA (A. Bosotti – INFN)
- **MOPVA064** Multipacting Studies in ESS Medium-Beta Cavity (J. Chen – INFN)
- **MOPVA068** Experience on Design, Fabrication and Testing of a Large Grain ESS Medium Beta Prototype Cavity (D. Sertore – INFN)

- **f = 1741.8 MHz** (> 19 MHz from machine line)
- **Δf < 1 MHz** from simulations (f =1742.4 MHz).
Cleanroom, RF Station, Assembly hall, Test Stand are ready in Saclay

First Medium $\beta$ String in CEA Saclay

Cleanroom

RF station: Power-coupler conditioning

Re-use the current infrastructure of XFEL
SML modulator topology successfully demonstrated on 120 kVA prototype

- Order of 3 units for NC linac by ESS-Bilbao
- On-going ESS tender for 9 units for MB linac

- Total footprint: 3.8m x 1.4m (planned was 5.5m x 1.6m, i.e. 40% less);
- Total weight: < 4 tons (without oil);
- Total volume of oil: ~ 2200 litters;
Klystrons and MB-IOT prototypes

THPIK084 Results from the 704 MHz Klystron and Multi-Beam IOT Prototypes For the European Spallation Source (M. Jensen – ESS)
Beam raster scanning on target

- Raster system sweeping beam in 2D pattern @ target
- 8 colinear magnets, individually powered
- Crosshatch pattern \((f_x/f_y, \phi_{xy}, a_x, a_y)\) within 2.86 ms pulse

\[<J>_{\text{max}} = 53.3 \, \mu\text{A/cm}^2\]
## Accelerator schedule

### NCFE

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
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<tbody>
<tr>
<td>2016</td>
<td>START RFQ MACHINING</td>
</tr>
<tr>
<td>2017</td>
<td>RFI ISRC &amp; LEBT</td>
</tr>
<tr>
<td>2018</td>
<td>RFI RFQ</td>
</tr>
<tr>
<td>2019</td>
<td>RFI MEBT</td>
</tr>
<tr>
<td>2020</td>
<td>RFI DTL5</td>
</tr>
<tr>
<td>2021</td>
<td>SC LINAC 570 MeV READY</td>
</tr>
<tr>
<td>2022</td>
<td>SC LINAC 2 GeV READY</td>
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### Spoke & Elliptical cavities and cryomodules

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
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<tbody>
<tr>
<td>2016</td>
<td>SPOKE CM TESTING STARTS</td>
</tr>
<tr>
<td>2017</td>
<td>MB CM TESTING STARTS</td>
</tr>
<tr>
<td>2018</td>
<td>SC LINAC 570 MeV READY</td>
</tr>
<tr>
<td>2019</td>
<td>1-11 HB CM INSTALLED</td>
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<tr>
<td>2020</td>
<td>12-21 HB CM INSTALLED</td>
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### RF

<table>
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<th>Year</th>
<th>Event</th>
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<tbody>
<tr>
<td>2016</td>
<td>CPI/THALES AND L3 IOT PROTOTYPES DELIVERED</td>
</tr>
<tr>
<td>2017</td>
<td>DECISION IOT OR KLYSTRON FOR HB LINAC</td>
</tr>
<tr>
<td>2018</td>
<td>RF SYSTEM FOR MB READY</td>
</tr>
<tr>
<td>2019</td>
<td>TECHNICAL STOP</td>
</tr>
<tr>
<td>2020</td>
<td>TECHNICAL STOP</td>
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### Cryogenics

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
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<tbody>
<tr>
<td>2016</td>
<td>ACCELERATOR CRYOPLANT COMM./READY</td>
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<tr>
<td>2017</td>
<td>CDS COMMISSIONED</td>
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<tr>
<td>2018</td>
<td>BEAM COMM. COMPLETED FOR ISRC-&gt;MEBT</td>
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<tr>
<td>2019</td>
<td>FIRST PROTONS ON TARGET</td>
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<tr>
<td>2020</td>
<td>1370 MeV PROTONS AVAILABLE</td>
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### Commissioning

<table>
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<th>Event</th>
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<td>START RFQ COMMISSIONING</td>
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<tr>
<td>2018</td>
<td>FIRST PROTONS ON TARGET</td>
</tr>
<tr>
<td>2019</td>
<td>2 GeV PROTONS AVAILABLE</td>
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Target Station high level functions

- Generate neutrons via the spallation process using protons produced by the accelerator
- Slow the neutrons to speeds useful for neutron scattering
- Direct neutrons to neutron scattering instruments
- Safe, reliable operation with high availability
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Ready for beam in March 2020
Target Station Partners

- DTU
- RACE
- Science & Technology Facilities Council
- Centrum výzkumu Řež s.r.o.
- Research Centre Rez
- JÜLICH FORSCHUNGSZENTRUM
- ESS
- ESS Bilbao
- Consiglio Nazionale delle Ricerche
Main components:

• Monolith:
  • Vessel (6 m diameter x 8 m height)
  • Steel shielding (6000 tons)
  • Instrumentation plugs
  • Proton beam window
  • Neutron shutters
  • Neutron beam extraction system

• Rotating Tungsten target
  • 2.5 m diameter x 10 cm height
  • 7500 Tungsten bricks (3.5 tons)
  • 0.39 rev./s

• Target He gas-cooling
  • 3 MW capacity
  • 3 kg/s flow rate
  • Dt = 200 degrees C

• High brightness moderators
  • 2 liquid H\textsubscript{2} moderators
  • Water premoderators and moderators
  • He cryoplant (35 kW – 16 K)
Main components:

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  - 3 MW capacity
  - 3 kg/s flow rate
  - $D_t = 200 \text{ degrees C}$

- **High brightness moderators**
  - 2 liquid $H_2$ moderators
  - Water premoderators and moderators
  - He cryoplant (35 kW – 16 K)
Fluid Systems and active cells

Fluid systems:
• Water cooling systems for thermal moderators, reflector and shielding
• Primary cooling system for proton beam window
• Intermediate water systems
• Helium purification systems
• Ventilation system

Active cell and remote handling systems:
• Hot cell and internals for processing and storing spent radioactive components
• Transfer casks to transport activated components on site
• Support systems (mock-up test stand, local shielding, etc.)
Installation has started!

ECHIR embedment inside the formwork for the monolith foundation

Concrete shielding blocks stacked inside the beam dump cave
The Integrated Control System (ICS) will serve the whole site

**Highlights**

- Integrated control system for Accelerator, Target, Instruments
- Full scale deployment of EPICS 7
- Full scale deployment of MTCA.4 - new innovative technology
- Ambitious approach to automation of control system configuration
- High performance requirements on the MPS to ensure availability
- Personnel Safety System (PSS) for access to radiation controlled zones

~ $1.5 \times 10^6$ control points!
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Red: Accelerator + Cryogenics zone
Yellow: Target zone
Orange/Violet: 1 zone/instrument
Blue: CF zone

ESS Network
ICS In-kind partners

Partner Institutes

- Atomki, Hungary
- CEA, France
- CNRS/IPNO, France
- Elettra, Italy
- ESS Bilbao, Spain
- IFE, Norway
- INFN Catania, Italy
- INFN Legnaro, Italy
- PSI, Switzerland
- STFC, UK
- Tallinn Technical University, Estonia
- ÚJV Řež, Czech Republic
- University of Łódź, Poland
- Uppsala University, Sweden
- ZHAW, Switzerland
First 15 Neutron instruments

ESS Lead Partners for instrument construction

ESS In-Kind Partners also collaborate on sample environment, data management systems etc.
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Organisation and People

- **401 Employees**
- **48 Nationalities**
- **> 45 Collaborating Institutions**
Construction funding & budget profile

ESS PROJECT BASELINE

- Construction Starts: 2013
- Initial Operations: 2019
- Project Completion & Closeout: Dec-2025
- Total Project Cost: €1,942 M
- % Completed (Earned Value): 32.1%
- Remaining work to Complete: €1,319 M
- Remaining Contingency: €126.7 M
- Contingency as % of Remaining Work: 9.6%
- Performance and Cost through: 31-Mar-17

Key Milestones:
- Construction Starts
- First installations (of Machine Systems)
- Machine Ready for Beam on Target
- Start of user programme

Graph:
- Total Funding (Cumulative)
- Total Baseline Budget incl. Contingency (Cumulative)
- Total Baseline Budget excl. Contingency (Cumulative)
- Total Earned Value (Cumulative)
- Total Actual Cost (Cumulative)

Timelines:
- 2013
- 2014
- 2015
- 2016
- 2017
- 2018
- 2019
- 2020
- 2021
- 2022
- 2023
- 2024
- 2025
Linac tunnel

Tunnel, view from HEBT

Front End Building
Cryo Compressor Building
Target
Monolith & Active Cells
Beam Line Gallery
8,000 m² base slab – last casting 14/03/2017
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Summary
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• ESS will be the world leading neutron spallation source after 2025.
• Starting from a greenfield site it is only possible thanks to the world-wide community knowledge.
• It is materializing thanks to the competences and efforts of many European partner institutions and of European industry.
• The project is on track for the start of the user program in 2023.
• The success of ESS will be a collective success of all those involved!

You are welcome to visit the ESS construction site on Friday!
Thank you!